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THE BEHAVIOR OF TWENTY-FOUR HEIGHT CHANGE PATTERNS  
AT 500 MILLIBARS

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ABSTRACT

The behavior of 24-hr height tendencies at the 500-mb level is studied for the fall of 1951. Several possible methods for determining the tendency pattern for the next day are tested quantitatively. The normal behavior of the centers is specified and some remarks included on unusual developments. Finally, extrapolation along the long-wave pattern is suggested as an improved technique for predicting the movement of the individual height-change centers.

INTRODUCTION Various meteorological authors have mentioned the use of 24-hr height-tendency patterns at the 500-mb level in their method of preparing surface and upper-level prognostic charts. Although there are these evidences of widespread use of these patterns, little has been published in English concerning their behavior.

The forecasting procedure outlined by Riehl (1) in his Forecasting in Middle Latitudes is based on the hypothesis that the flow at this level in the mid-troposphere can be treated as the sum of two wave trains, the long and short waves. These short waves frequently coincide with 500-mb, 24-hr, tendency centers; the isallobaric fall center with the short-wave trough and the isallobaric rise center with the short-wave ridge.

A. Nyberg (2) has reported success in moving the tendency centers with 50 per cent of the 500-mb wind in the center. This view is also given some support by Namias (3) in his study of the seasonal variation of the zonal wind. A similar study by Mansueto (4) at 700 millibars showed a somewhat lower correlation.

The purpose of this study is to test the hypotheses which have been presented and to attempt to formulate a set of principles to be followed in determining a prognostic-tendency pattern for a 24-hr period.

METHOD The diurnal variation in height of the 500-mb surface is not precisely known. Hubert (5) has found that the half period of the variation of height of the 500-mb level over Columbia, Missouri averages 1.7 days. From these considerations, it is indicated that twenty-four hours is a good choice of tendency interval, since it eliminates any diurnal effect and is shorter than almost all half periods of the tendency.

Hemispheric-tendency charts were prepared daily during the fall of 1951, using the graphical subtraction method on carefully analyzed charts drawn with a 200-ft contour interval.

The individual centers were tracked from day-to-day. The direction and speed of movement as taken from the straight line connecting 24-hr positions, the wind in the center, and the shape and intensity of each center was tabulated. A total of 88 centers were considered. 52 for the period 7-18 October and 36 from 30 October to 20 November.

Tables and graphs were prepared showing the movement of the centers, the relation between average wind in the center and movement. A vector average of the wind in the center at the beginning and end of the 24-hr period was used as the average wind in the center. This assumption is convenient and somewhat more representative than a simple arithmetic average of directions and speeds.

STATISTICAL RESULTS A check was initially made to determine how valid the assumption that centers of rise and fall could be tracked at 500 millibars. Although few cases were found in which all centers were conserved from one day to the next, a very great majority were. However, changes in intensity were the rule. Sixty percent of 35 centers in this check were tracked from the point of their appearance until they entered Asia. In some cases this was over 100° of longitude.

The first approximation tested was that the tendency centers could be moved a fixed distance. If the expected error were sufficiently small, this might represent a useable prognostic technique. In the period 7-18 October, the movement of rise and fall centers was tabulated from charts in the area 150°W eastward to 0°E. The distribution of 24-hr movement is as follows:

TABLE I

Movement in nautical miles	250	350	450	550	650	750	850	950
Percent in this class	7	13	15	23	19	13	7	4

The average movement is 560 nautical miles. The probable error in using this as an estimate, would be nearly  $\pm 200$  nautical miles.

From this data, it is obvious that all tendency centers cannot be moved with a constant displacement. The method would occasionally result in a satisfactory prognosis, but certainly not very often.

Next, an extensive check was made of the hypothesis that the tendency centers move with some fraction of the wind in the center. The hypothesis of Nyberg (supported by Namias), of the tendency centers moving with a fixed percentage of the wind in the center, is untenable. The average wind speed in the isallobaric centers increased from 35 knots for the period 30 October-20 November, while the average displacement of the centers was 23 knots for the first period and only 21.5 knots for the second.

Indeed, the distribution of wind speed vs. displacement is nearly random. The direction of movement came out somewhat better, with a probable error of  $\pm 20^\circ$  from the direction of the mean wind in the center. Combined, the expected vector error would be about 200 nautical miles. This is approximately the same as the error if all centers were moved 560 miles. From these considerations, it is obvious that the normal behavior of 500-mb, height-change centers is poorly correlated with the zonal wind or the 500-mb wind in the center. If this behavior is to be predicted, other considerations must be

used. Unfortunately, the late time at which this conclusion was reached and the small reliable sample of data available, precluded the quantitative testing of some of the observations that follow here. However, they are set down as an indication of lines of future investigation and with the belief that these tendency centers will eventually be calculated or otherwise predicted in so nearly a correct fashion as to produce a 500-mb, 24-hr, prognostic chart which can be used with confidence in the preparation of a surface forecast.

#### NORMAL BEHAVIOR OF 500-MILLIBAR M 24-HOUR PATTERNS

The height of any isobaric surface in the atmosphere is a function of events that may take place well above and below that surface. Thus, there is no physical reason evident why the winds on the 500-mb surface should correlate well with the movement of the height change centers on this surface. Of course, if such a good correlation were discovered, it should be used, regardless of the theoretical connotations.

The intensity of the change centers is greatest in winter and least in summer. The normal shape does not change. Centers are generally elongated meridionally with the N - S axis normally 2 - 4 times the E - W axis. Any elongation E - W is abnormal. The center intensity varies directly in proportion to the geographical size in general and the gradient is normally constant on all sides and from the 400-ft isallobar to the tendency center.

The future movement of centers may best be estimated by extrapolation of movements, keeping in mind the fact that the paths of the centers tend to trace out the long-wave pattern. In the November sample of data, the comparison of direction of actual movement against the direction of the mean wind in the center shows eighteen cases of left deflection; while only six cases show right deflection. Most of these movements were tabulated over Eastern United States with a mean position of the long-wave trough in Western United States. The October sample shows random directional variation. This sample was for centers located from 150°W and 0° without any particular location in the long-wave pattern.

24-hr tendency centers generally mark positions of short-wave troughs and ridges. Some patterns occasionally show marked deviation from this rule, especially when long waves are markedly progressive. In this case, as was observed October 10-11, the tendency centers are near the inflection point of the composite wave pattern.

The short-wave number averaged 8 for the hemisphere during the period 7 October to 10 December 1961. The smallest short-wave number was 6 and the longest 10 1/2. This count was for the major short-wave train.

In stage N2 of the index cycle, the short-wave number tends to be high. The centers are large geographically and intense. Their shape shows marked N-S elongation and their movement is slower than normal. Only one train of tendency centers is present.

Extrapolation along the long-wave pattern offers the best method of moving-tendency centers. Change in intensity is another problem. The intensification of short-wave troughs approaching long-wave troughs is

observable. However, this intensification need not necessarily be accomplished by a numerical increase in the 500-mb tendency fall. An intensification of the bounding ridges can accomplish the same result. This extrapolation is therefore somewhat inadequate in direction and speed, and markedly so in change of intensity. Certain departures from normal extrapolative behavior are included below. Some of these observations are drawn from a rather small sample of data.

ABNORMAL BEHAVIOR OF TENDENCY CENTERS In 16 instances, a tendency center was observed to be oriented East - West. In nine of these cases, the center did not follow the extrapolated motion for the next 24 hours. Splitting of the center, slow movement of the westward portion, and movement at right angles to the wind flow were observed.

When the upper-fall center is associated with a deepening - surface low, it will deviate from its previous path toward the low and will increase in intensity.

When energy impulses are present which move with the group velocity, sudden increases in intensity of centers are common. Several such impulses were tracked for a large part of the hemisphere.

When instability is present in a ridge due to a curvature in excess of the maximum, a new rise center should appear to the left of the current downstream and a new fall center to the right of the current still further downstream. This effect was noted in two cases, although in the second case, the new fall center was indistinct being in the area of another fall.

When the number of tendency centers increases, they tend to slow down and vice versa. This was observed from a limited sample also.

### CONCLUSION

It is believed that 500-mb height tendencies are a valuable tool in weather prognostication, because they represent the effect on the pressure field of the events occurring in the upper troposphere. Extra-polation of the centers using the principles set down here will result in a pattern from which the sequence of subsequent surface events can be deduced. This 500-mb prognosis will be imperfect however, for although the path of these centers can be extrapolated fairly well using qualitatively the other considerations, the changes in intensity remain a complex problem. With possible effects moving downstream with the group velocity and upstream nearly instantaneously, it is obvious that a complete solution to this problem can never come from a statistical approach to the centers at the 500-mb level.

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